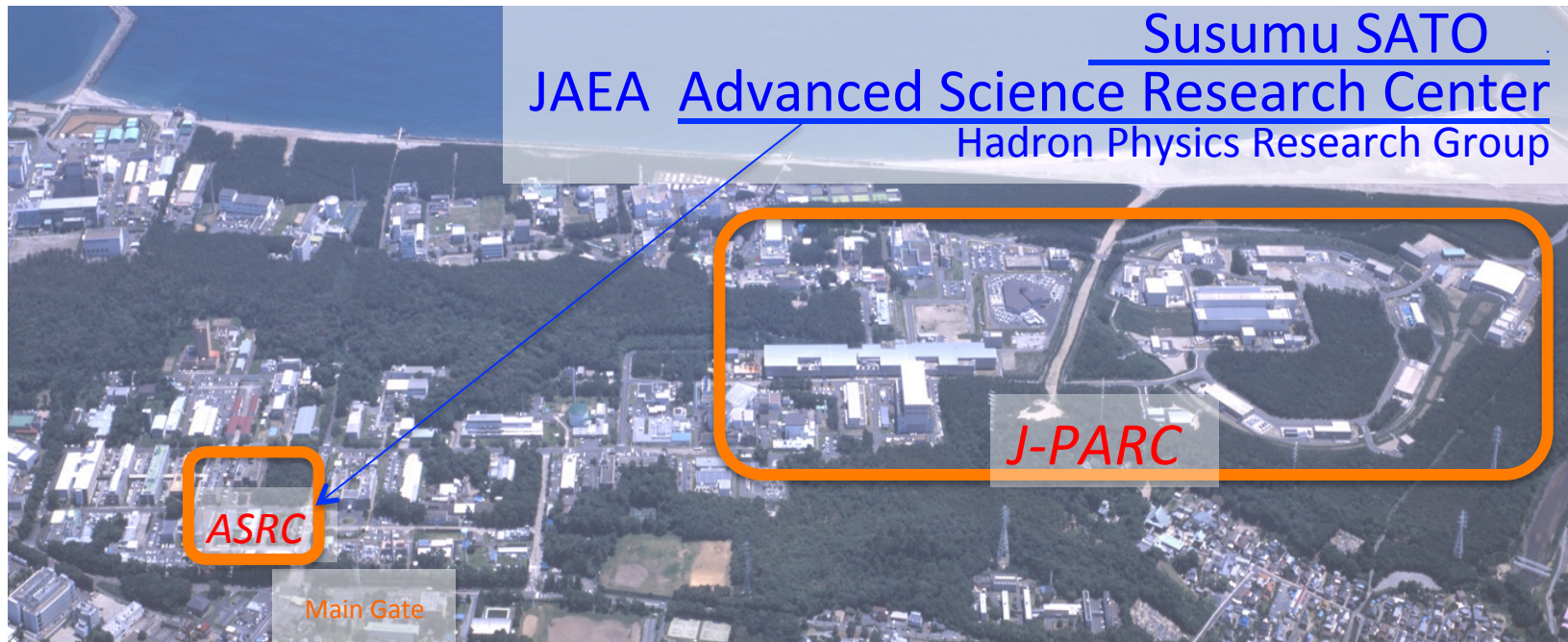


Future J-PARC experiment to Search for H particle



Contents

- o Introduction
 - H-dibaryon, Theoretical expectation, Observation
- o Letter of intent
 - Proposed setup at J-PARC, Prototype, Expected yield
- o Progress on accelerator of J-PARC
 - Improvement of Spill, Intensity
- o Summary

H-dibaryon

- A predicted compact 6-quark (uuddss) state
 - R.L. Jaffe, Phys. Rev. Lett. 38 (1977) [MIT bag model]
 - Which is 35 years ago. One of most famous candidate exotic-hadron, but still not observed.
 - No Pauli exclusion, Flavor singlet state
 - Bound State ($B_H > 7$ MeV is ruled out by $_{\Lambda\Lambda}\text{He}$) or Resonance

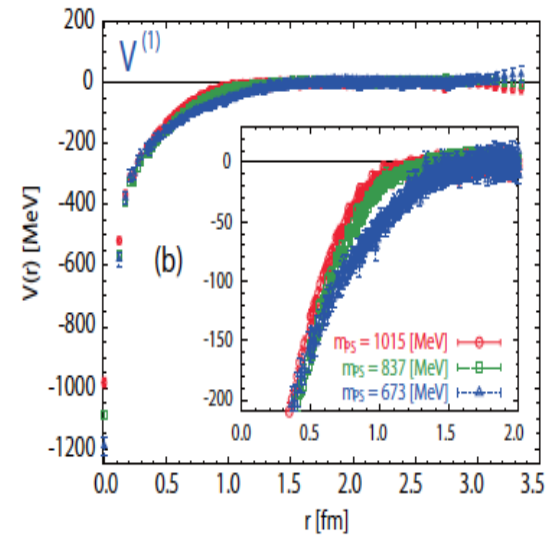
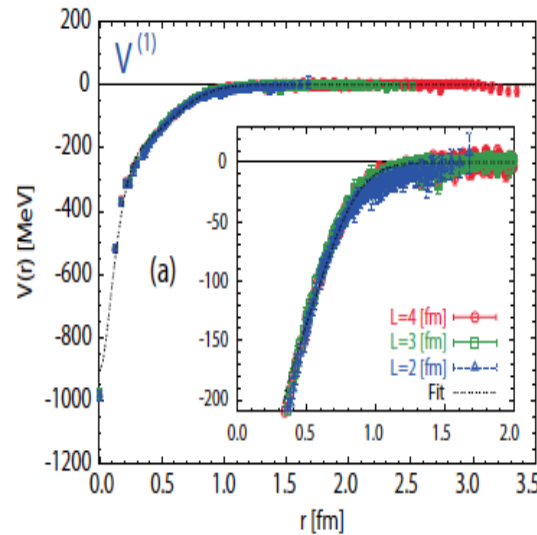
Recent Lattice Calculations

Lattice calculation (HAL) gives:

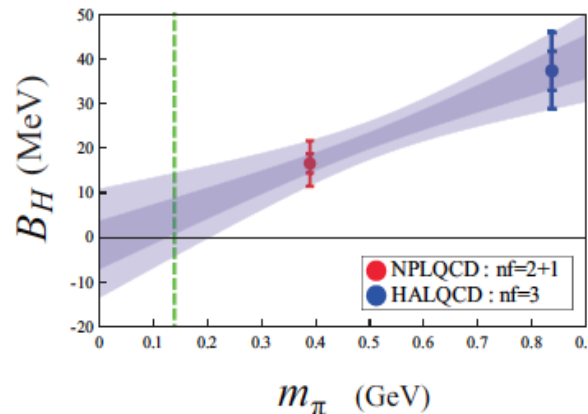
- Nuclear force, attractive potential at long distance & short range repulsion was produced by the first principle.

- Extended to baryon-baryon interaction including hyperons under $SU_f(3)$ symmetry.

- Singlet state, H-dibaryon state, shows no repulsive core but attractive potential. (regardless of lattice size of 2 to 4 fm, and pion mass of 1015 to 673 MeV)



T.Inoue et al. (HAL coll.) Phys Rev. Lett 106 (2011)162002

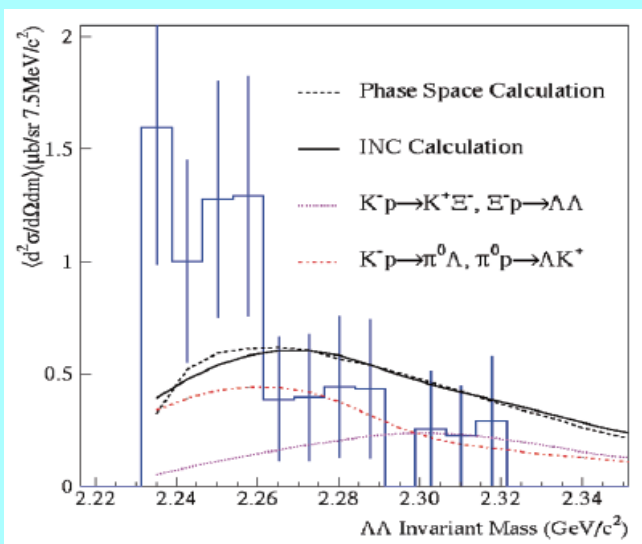


S.R.Beane et al. (NPLQCD coll.) arXiv:1103.2821v1 [hep-lat] (2011)

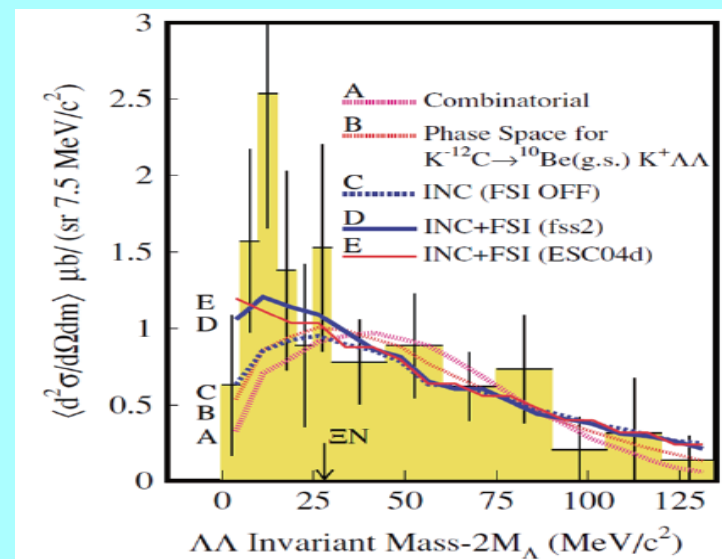
Binding energy extrapolated by HAL and NPLQCD lattice calculation shows B_H is around $\Lambda\Lambda$ threshold

Trials in the History

- KEK-E224 and KEK-E522 have shown interesting object in $\Lambda\Lambda$ invariant mass.



[E224] Observation in $^{12}\text{C}(K^-, K^+)$ above $\Lambda\Lambda$ threshold. [J.K.Ahn et al. PLB444 (1998) 267]



[E522] More statistics. Then resonance (or final-state-interaction) at 2242 MeV (12 MeV above $\Lambda\Lambda$ threshold). [C.J. Yoon et al. PRC75 (2007) 022201]

Letter of Intent

- We prepared LOI and Proposal to meet coming rapid increase of J-PARC intensity for K-beam.
- Handed in to J-PARC PAC, in Jul 2011, [J.K. Ahn](#), [K. Imai](#), et al. "Search for H-Dibaryon with a Large Acceptance Hyperon Spectrometer".
- Intra-nuclear cascade model calculations developed by [Y.Nara](#), [A.Ohnishi](#) [T. Harada](#), et al. e.g. arXiv: nucl-th/9608017v1 are the theoretical pilot of the letter .

KEK_J-PARC-PAC2011-03

Letter of Intent for 50 GeV Proton Synchrotron

Search for H-Dibaryon with a Large Acceptance Hyperon Spectrometer

J.K.Ahn*, B.H.Choi, S.H.Hwang, S.H.Kim,
S.Y.Kim, J.K.Lee, J.Y.Park, S.Y.Ryu
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S.Hasegawa, R.Honda, Y.Ichikawa, K.Imai*, R.Kiuchi, H.Sako,
S.Sato, K.Shirotori, H.Sugimura, K.Tanida
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H.Fujioka, T.Nagae, M.Niiyama
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R.Kiuchi, K.Tanida
Seoul National University, Korea

M.Ieiri, K.Ozawa, H.Takahashi, T.Takahashi
High Energy Accelerator Research Organization (KEK), Japan

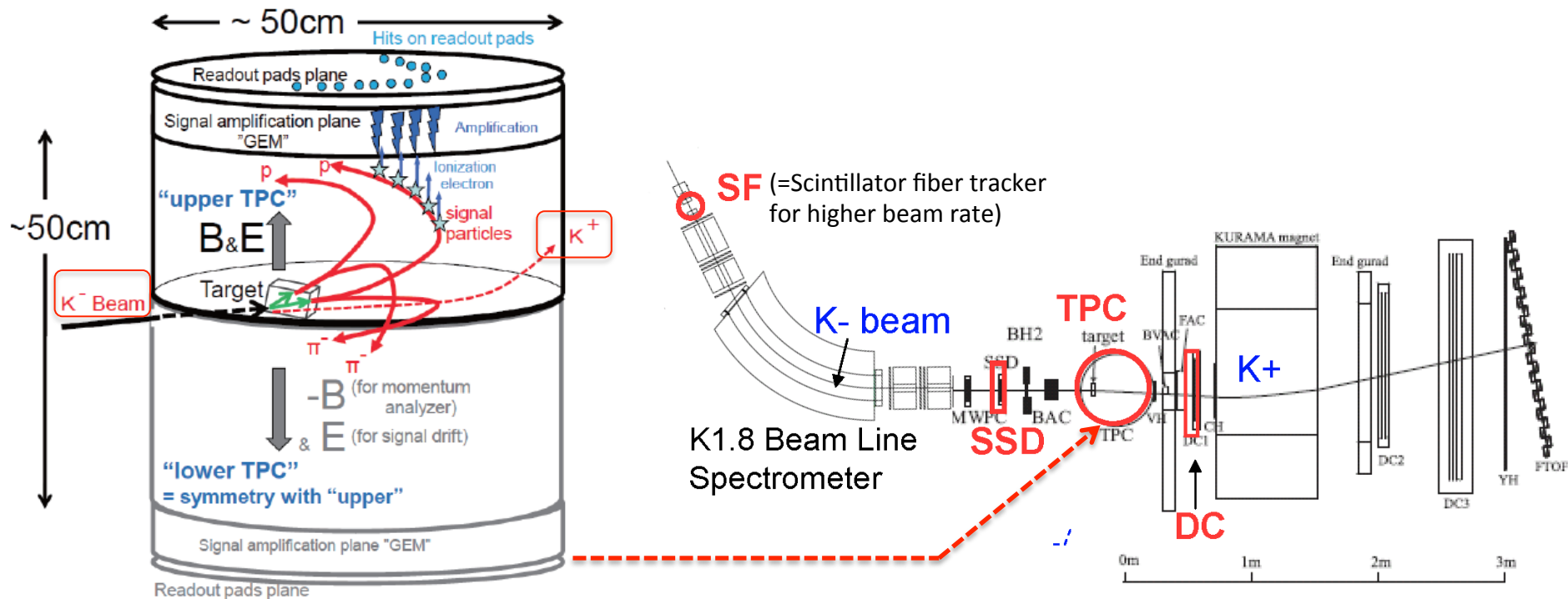
K.Nakazawa, M.Sumihama
Gifu University

B.Bassalleck
University of New Mexico, USA

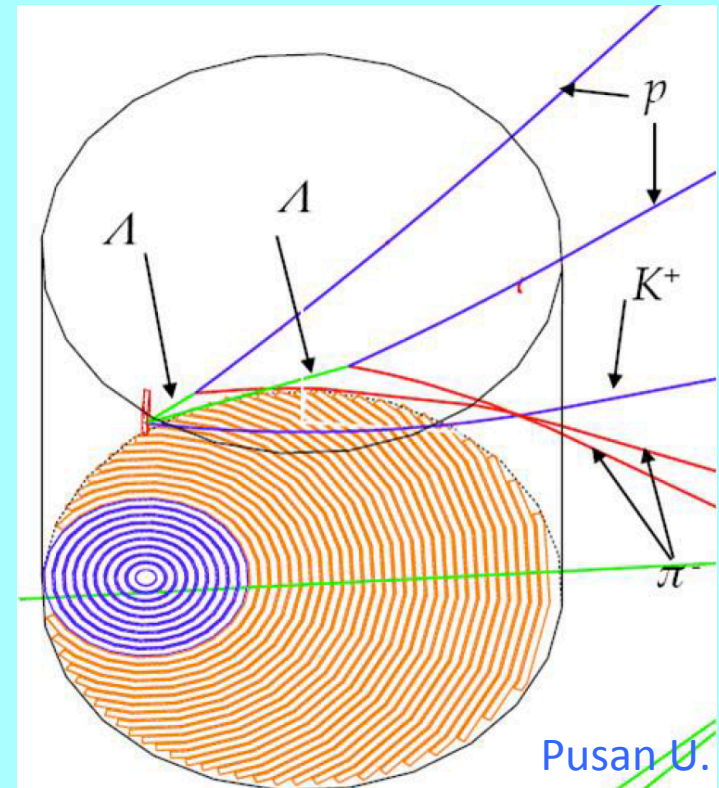
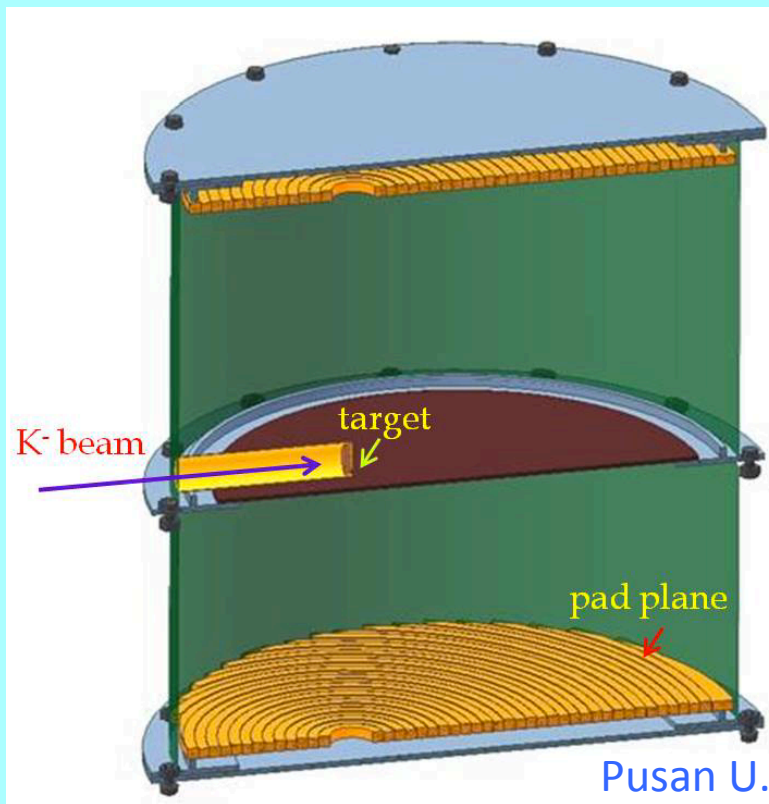
(* indicate contact persons)
6 July, 2011

Proposed Spectrometer

- Larger acceptance in the Helmholtz-type (super conducting, T-class) magnet.
- 3-D tracking with higher rate (upto 10^6 Kaon beam, highest in J-PARC) with gating performance.

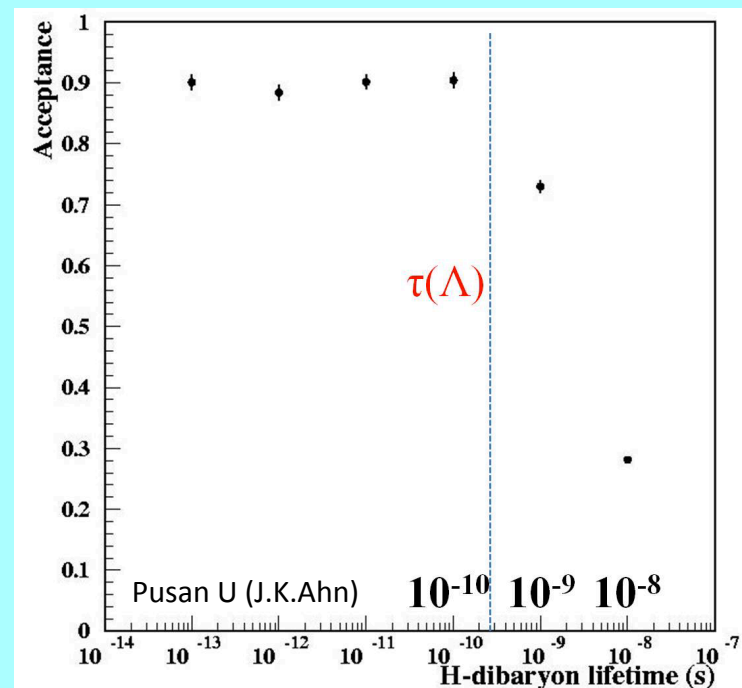
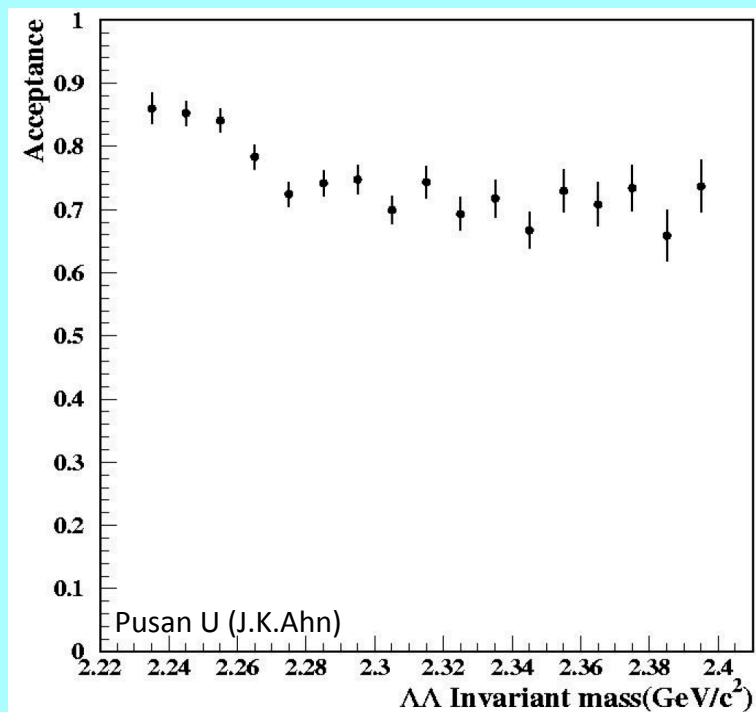


Example of TPC configuration and simulated $\Lambda\Lambda$ event



For each plane on top and bottom,
6000 pads in 10 ~ 38 pad layers (L:10mm gap:3mm)

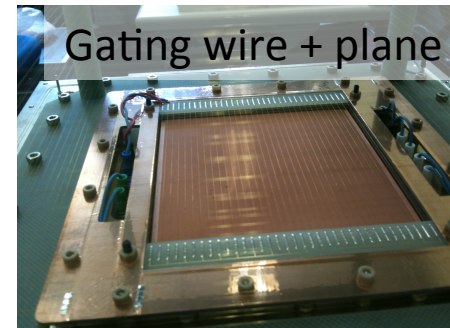
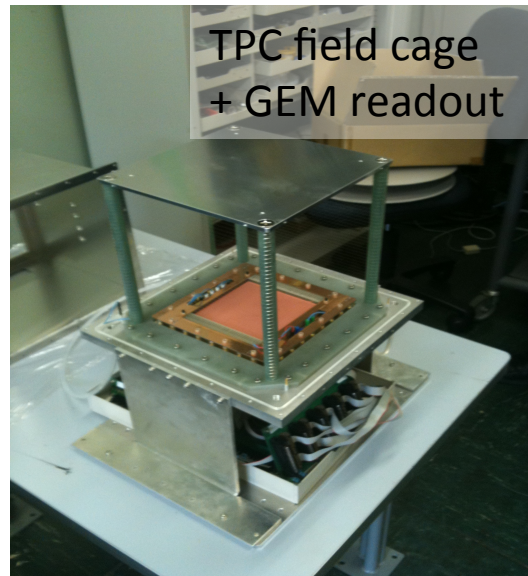
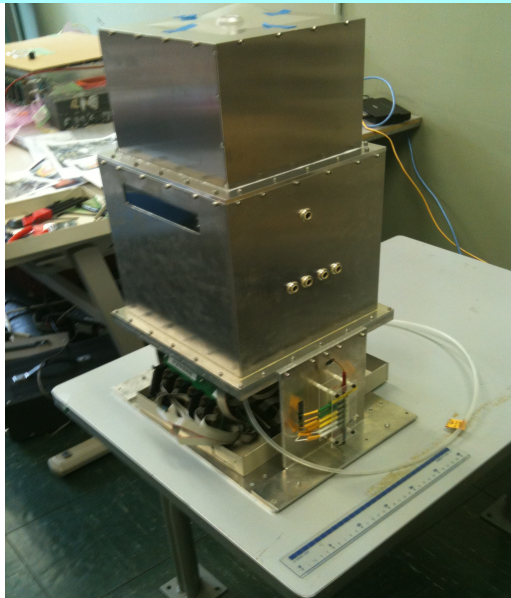
Sensitivity to Mass and Lifetime



- The detection efficiency was estimated to reach almost 0.9 by requiring that a particle should pass more than 8 pad layers.
- Good sensitivity to the whole mass region of our interest for the H above threshold, and to the lifetime shorter than 10E-9 sec for the H \rightarrow $\Lambda p \pi^-$ decay.

Prototype

TPC 20cm drift x 10cm x 10 cm square,
 (1) 7 kV \rightarrow 16 kV for TPC field,
 (2) ± 0.7 V for gating field,
 (3) 3 kV for 3 planes GEM + drift space
 HV module is capable independent voltage setting.



R&D items at RCNP in 2011 Nov/Dec

- (i) GEM with read out 2D pad (width 2, 3, 4 mm)
- (ii) Gating wire with a field guide plane (± 150 V) up to $10E6$.
- (iii) Gas (P10, CF₄+Ar)

To reduce ch.#
 To reduce gate noise

More items to be tested at test bench.

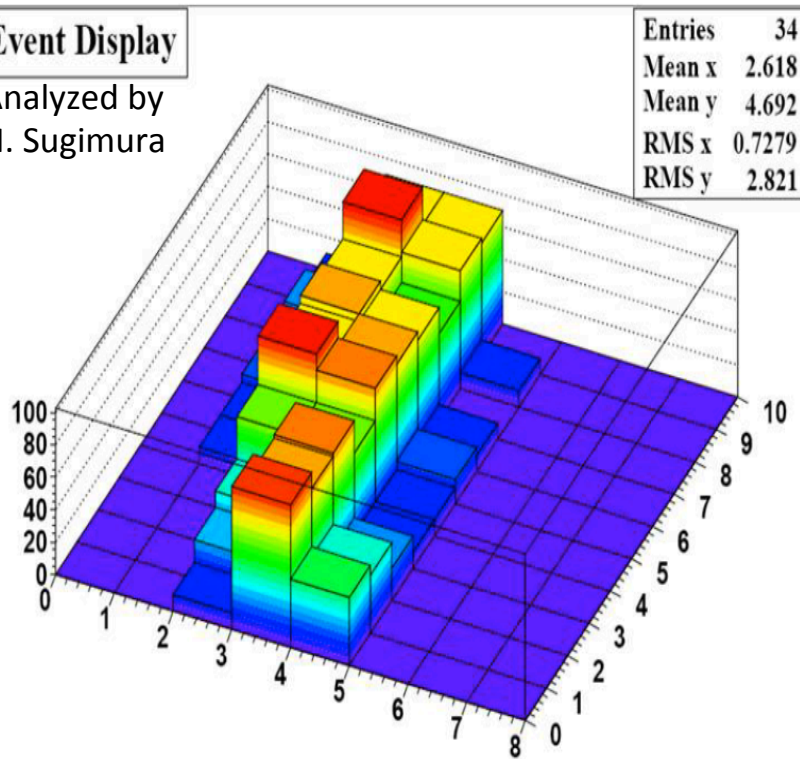
- (i) muPIC (1D+1D) readout (with 0.4mm pitch)
- (ii) gating operation at GEM(\pm few 10 V)

Performance of Prototype

(RCNP-E384, Nov 2011, 400MeV proton)

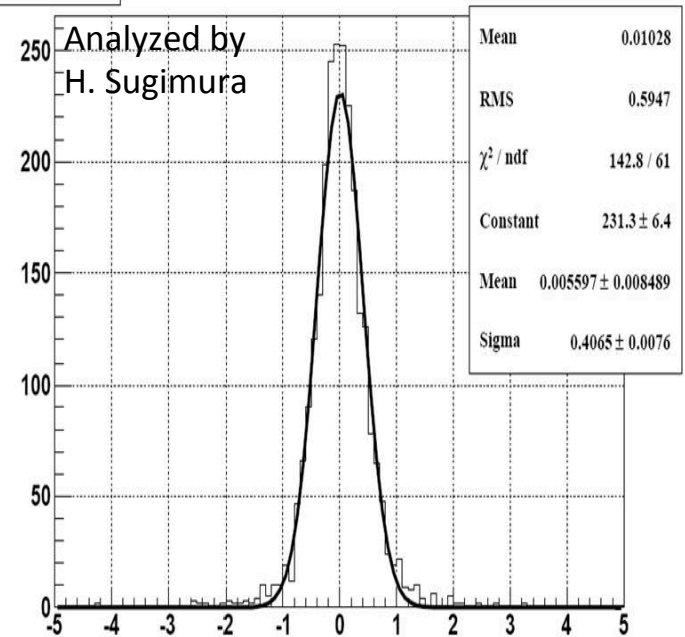
Event Display

Analyzed by
H. Sugimura



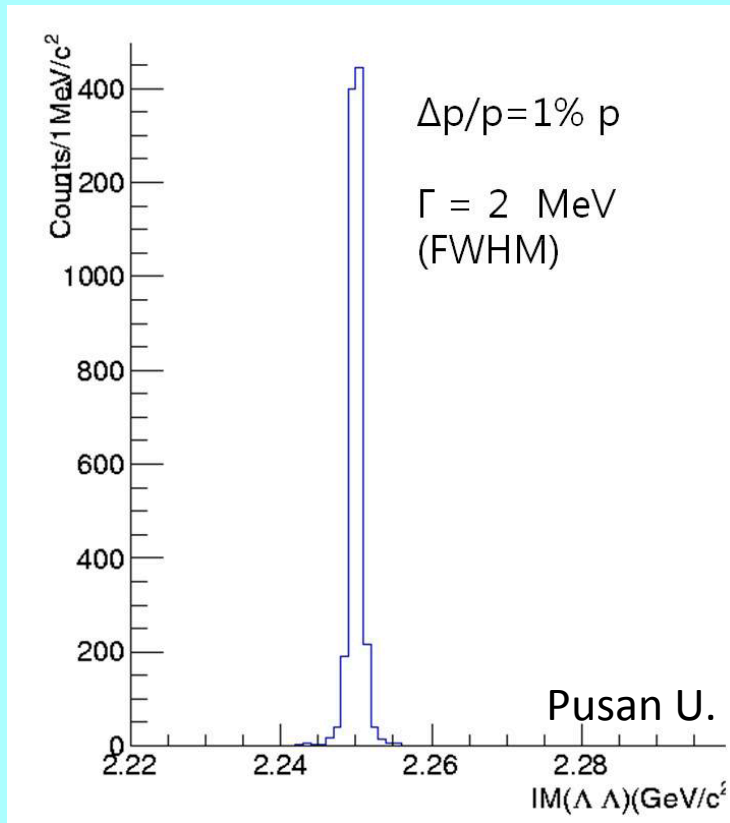
residual

Analyzed by
H. Sugimura



Hit pattern distribution (left), and Residual distribution (right) with sigma \sim 400 μm .

Mass resolution

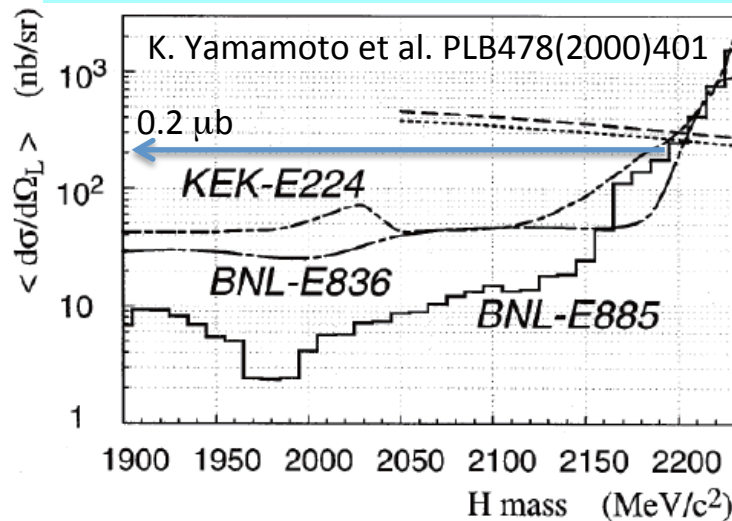


With a position resolution of 300 μm , the pion momentum resolution of about 1% is expected at 300 MeV/c.

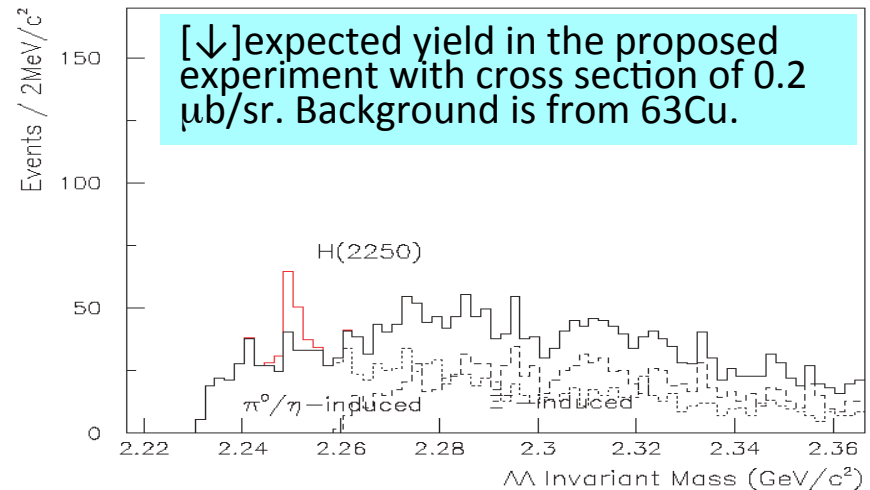
Mass resolutions is
 $\Gamma = 2 \text{ MeV}$ for $\Delta \mathbf{p}/\mathbf{p} = 1\% \mathbf{p}$,
and $\Gamma = 3.5 \text{ MeV}$ for $\Delta \mathbf{p}/\mathbf{p} = 3\% \mathbf{p}$.

Expected Statistics

[↓] 90% C.L. upper limits on the direct H production cross section on 12 C and 3He. The dashed line shows a theoretical calculation for 12C and 3He based on the model of Aerts and Dover (PRD28(1983)450)



Many experiment is performed and excluded H dibaryon mass upto 2200 MeV, But the experiments were not sensitive to this cross section if H-dibaryon mass is near $\Lambda\Lambda$ threshold because of large tail of quasi-free Ξ^- production.

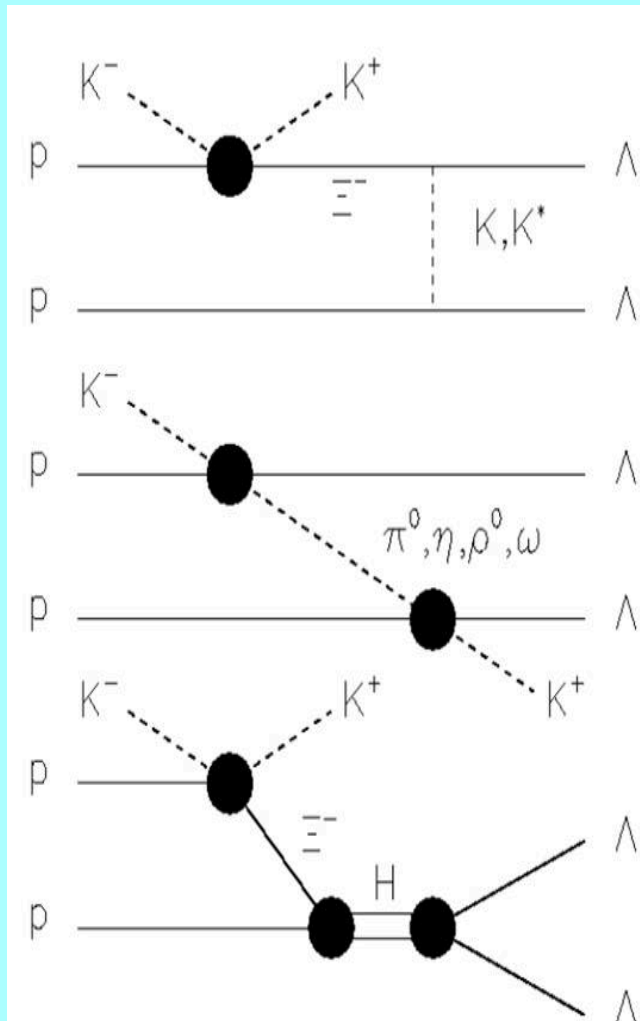


Parameters	Values
K^- beam	$10^6 K^-$ per spill (6 second)
Cu target	4.25×10^{22}
$d\sigma/d\Omega_{\Lambda\Lambda}^{Cu}$	$14.6 \mu\text{b/sr}$
$\Delta\Omega$	0.11 sr
Branching ratio ($\Lambda \rightarrow p\pi^-$)	0.64
Detection efficiency of K^+ with Kurama	0.5
Detection efficiency of two Λ with TPC	0.5
Yield	0.007 event / spill

3300 $\Lambda\Lambda$ -events \leftrightarrow 0.007 events / spill

If $d\sigma_H/d\Omega = 0.2 \mu\text{b/sr}$, in 100shifts (3 shift / day), 46 H-events are expected

(K^-, K^+) reaction for $\Lambda\Lambda$ production



(1)

Ξ^- interacts with a proton in the same nucleus to produce $\Lambda\Lambda$.

(2)

Λ is produced with an intermediate meson in K^-p reaction and then the meson interacts with a proton in the same nucleus to produce the other Λ and K^+ .

(3)

Ξ^-p fuses to H which decays into $\Lambda\Lambda$.

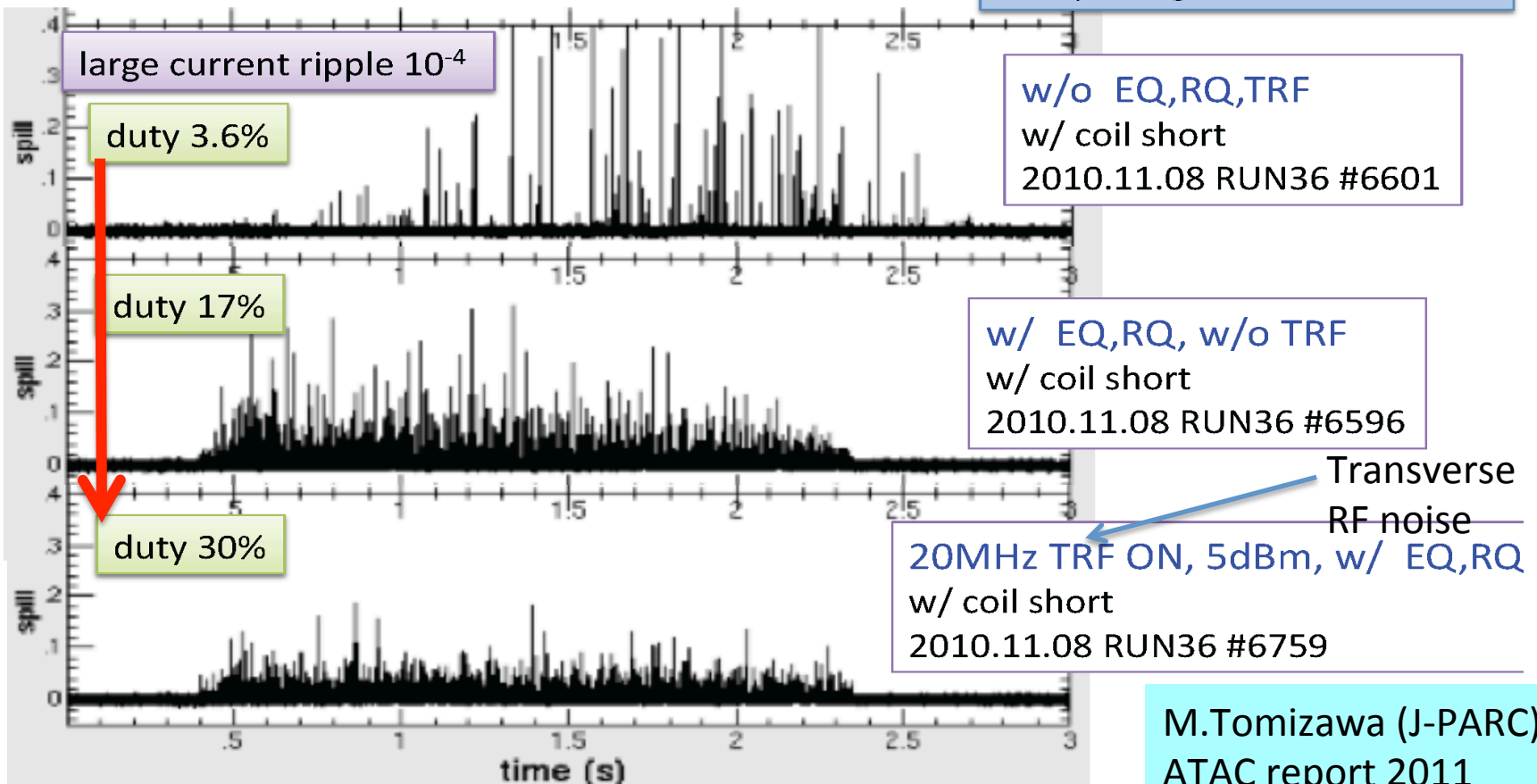
whereas J-PARC accelerator has been trying to

- Recover from the Earthquake
 - Up to some tens mm shift in the beam lines.
 - In Feb. 2012, hadron hall re-started experiment with beam back!
- Improve fluctuation in the in-spill structure
 - By the smoother with RF to randomize spill spiking.
- Increase Intensity
 - Upgrade LINAC in 2013 summer (181MeV -> 400 MeV) by adding the ACS-type cavities (324×3 MHz).
 - Improve diagnostics in the LINAC, looking longitudinal (as well as existing transverse) beam structure, with RF .

For Secondary (K, π) Beam in Hadron Experiment , Beam extraction Spill structure improvement

$$DutyFactor = \left[\int_0^T I(t) dt \right]^2 / \left[\int_0^T dt \cdot \int_0^T I^2(t) dt \right]$$

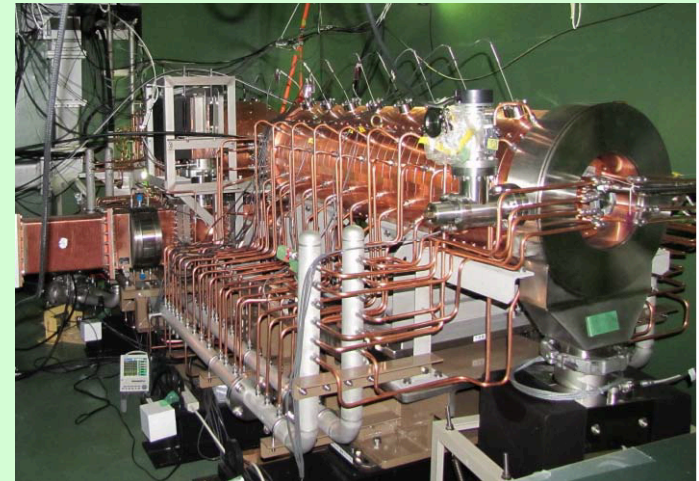
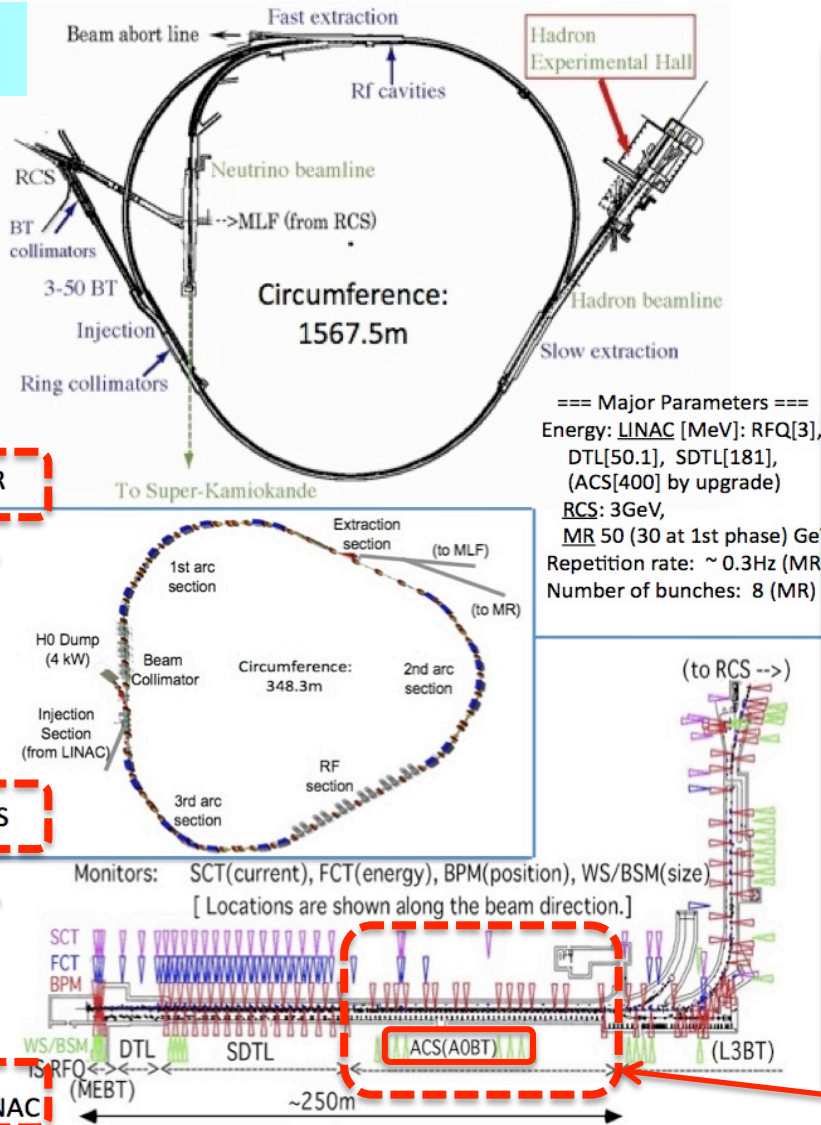
$I(t)$: PM signal sampled at 100KHz
through 10KHz LPF
 $t=0$: spill start
 $t=T$: spill length



M.Tomizawa (J-PARC)
ATAC report 2011

For J-PARC power LINAC ACS upgrade (181MeV->400MeV)

S.Sato
ICPAQGP



N.Ohuchi (J-PARC) ATAC report 2011

	2009	2010	2011	2012
ACS2	▼contract		▼Klystron ready	Installation & Beam test
ACS3				
ACS4				
ACS5			High-power RF test	
		Fabrication		
ACS19				
ACS21				
DB1				
DB2				

Summary

- H-dibaryon is predicted in 35 years ago.
- Some historical trials are performed for hunting the exotic hadron.
- A letter of Intent for experimental revival at J-PARC is prepared.
- A spectrometer, including prototype, is being R&D'ed to meet the coming rapid improvements of J-PARC accelerator.



Note

Signal :

H production cross section is estimated based on the KEK-PS E224 measurement of enhanced Λ - Λ pairs from ^{12}C near the Λ - Λ threshold .

“Background”:

$\Lambda\Lambda$ production cross section is estimated from ^{63}Cu based on the measured $^{63}\text{Cu}(\text{K}^-, \text{K}^+)\text{X}$ cross section in KEK-PS E176.